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Three decades of cetacean strandings in Western Australia: 1981 to 2010

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Western Australia has an extensive coastline that provides a range of marine habitats for cetaceans. This paper constitutes the first comprehensive review of cetacean strandings in the region. From 1981 to 2010, stranding events were reported to the Western Australian Department of Environment and Conservation and recorded in the Western Australian Cetacean Stranding Database. During this period a total of 732 cetacean stranding events have been recorded, involving 34 species and 1753 individuals. Bottlenose dolphins (*Tursiops* sp.) were involved in the most stranding events (n = 330), while long-finned pilot whales (*Globicephala melas*) accounted for the largest number of individuals (n = 446 individuals involved in 22 stranding events). The southwest of the State is the region with the greatest number of reported stranding events. Sixty percent of stranded individuals were found alive. Over 70% of stranded cetaceans found alive were returned to deeper water.

KEYWORDS: cetacean, dolphin, stranding, Western Australia, whale.

INTRODUCTION

The coast of Western Australian stretches for 12 889 km (excluding islands), covers a wide latitudinal range and includes a range of marine habitats. Western Australia has the most diverse cetacean fauna of all Australian states with 37 species confirmed to be present (Bannister *et al.* 1996). With such an extensive coastline many sick, injured or dead cetaceans are encountered each year.

Prior to 1981 there was no formal process in place to maintain accurate records of stranding events in Western Australia and only a portion of events were captured through specimen records of the Western Australian Museum. In 1982 the Western Australian Cetacean Stranding Database was created. Reports of cetacean incidents (i.e. stranding, entanglement, ship/vessel strike etc) on the Western Australian coast are now routinely made to the Western Australian Department of Environment and Conservation (DEC) and recorded in the database. The department is responsible for administration of the Wildlife Conservation Act 1950 and managing issues relevant to fauna as defined under the Act, which includes whales and dolphins (cetaceans). In this capacity, DEC staff attend strandings either to investigate the cause of death of animals or to assess the live animals to determine what action, if any, is required (e.g. rescue attempt, euthanasia) and consequently are the major source of information in the database. In a small number of cases information was obtained from other government officers (e.g. officers from the Department of Fisheries), or from members of the public. The data presented here do not include records of healthy uncompromised animals that were sighted frequenting Western Australian waters and required no assistance or intervention. Skeletal and DNA materials are made available to the Western Australian Museum (WAM) but those records maintained at WAM are not as comprehensive as those received and validated by the DEC. Reports of incidents received by WAM are referred back to DEC in accordance with the Wildlife Conservation Act 1950.

Stranded cetaceans provide a unique opportunity to collect DNA, tissue samples, morphometric data and demographic data that contribute to our knowledge of the biology of these species. There are some species which are known only from stranded specimens (e.g. Andrew's beaked whale, *Mesoplodon bowdoini*) (MacLeod *et al.* 2006). Assessments of strandings have been used for a number of purposes including determining baseline mortality trends for assessing population health (Bogomolni *et al.* 2010), assessing the impact of human interaction on cetaceans (Kemper *et al.* 2005), assessing the impact of increased water temperature on cetacean communities (MacCleod *et al.* 2005) and obtaining information on the distribution, biology and ecology of species.

Limited information has been published on cetacean strandings along the coast of Western Australia. Those articles that have been published relate to particular stranding events (Anonymous 1981; Edwards 1987; McNamara 1987; Mell 1988; Gales 1992) or a particular taxonomic group (e.g. beaked whales: D K Coughran unpubl. data). Basic stranding data from Western Australia have also been included in general assessments of the conservation needs of cetacean species (Bannister *et al.* 1996). However, a comprehensive review of strandings in the region has not previously been undertaken.

This study aims to describe the cetacean fauna of Western Australia based on the stranding record, identify patterns in the spatial and temporal distribution of stranding events and assess the outcomes of stranding events (died, returned to deeper water etc). We also discuss the conservation and management implications of the findings.

METHODS

In Western Australia, any observations of stranded cetaceans that require some form of management are reported to DEC and an appropriate response is initiated ranging from noting the report to a full-scale rescue operation. The events and their outcomes are recorded in the Western Australian Cetacean Stranding Database and the records in this database were used for this study. These reports are investigated and validated by DEC before entry into the database by the database custodian who has maintained the database since it was created. Records of cetaceans recorded between 1981 and 2010 (29 years) are analysed here.

For the purposes of this paper a stranding may be defined as any event involving the beaching or washing up onshore of live or dead cetaceans, but also includes dead cetaceans floating within State waters (i.e. up to three nautical miles offshore). Incidents where some individuals from a group stranded and the rest were behaving in a manner that suggested they too would strand without intervention were also considered stranded. This is similar to other studies that refer to out-of-habitat or near-mass strandings also being included in analyses of strandings (Aragones *et al.* 2010). Each record in the database represents a single event. Each event may involve multiple individuals as it is not uncommon for a cow and calf to strand together or, for some species, an entire group to mass strand. A mass stranding was defined as any event involving three or more individuals of the same species. This approach means that mother–calf pairs are not included as mass strandings. It was sometimes difficult to decide if an event was a mass stranding or separate unrelated individual strandings if there was significant spatial (e.g. 20 km) and/or temporal (i.e. multiple days)spread between individuals or reports. For large mass-stranding events it was sometimes not possible to accurately count the number of individuals, particularly for events involving tens or hundreds of individuals, and so for these events the numbers reported should be considered estimates. Records where species identification was uncertain have been excluded from the study.

We categorised the outcome of stranding events in terms of the fate of individuals. The existing database does not clearly store this information and so notes in comments fields and the original paper records were consulted to assign individuals to an outcome category. Each individual was assigned to one category only, although events involving multiple individuals meant that different individuals from the one event may have been assigned to different outcomes (e.g. a mass-stranding event where some individuals died whilst others were returned to deeper water). The categories used were: found dead; died; euthanased; returned to deeper water; restranded and died; restranded and euthanased; restranded and returned to deeper water; taken into care and died; taken into care and returned to deeper water; and unknown. Those categorised as 'returned to deeper water' had either involved a rescue operation or tidal changes had occurred enabling the animals to refloat and return to deeper water. Those categorised as restranded had been returned to deeper water but had subsequently returned to shore and therefore required further intervention. We did not examine the information recorded for stranding events to identify possible causes of stranding. For records where a total length measurement was recorded, an age category was allocated to each individual based on age/length species information (Bannister *et al.*1996).

We analysed spatial and temporal trends in the number of strandings. The spatial distribution of strandings was summarised in relation to the Integrated Marine and Coastal Regionalisation of Australia (IMCRA) meso-scale bioregions. The bioregions were developed to provide a framework for planning resource development and biodiversity conservation (Commonwealth of Australia 2006). These bioregions are referred to in managing fisheries and in planning a comprehensive and representative marine reserve system. For those stranding records occurring along rivers or in estuarine environments, they were allocated to the nearest IMCRA region. The seasonality of stranding records was assessed by investigating the number of records by month for each species with more than 20 records. Pearson's chi-squared test was used to determine whether the stranding frequency varied significantly by season.

To aid discussion, we grouped species that stranded into four broad categories: dolphins, toothed whales, baleen whales and beaked whales (Table 1). The taxonomic group Delphinidae has some members that have been allocated to 'dolphins' and others to 'toothed whales'.

The taxonomy used in this paper follows Bannister *et al.* (1996). The taxonomy of bottlenose dolphins around the world is confused by the identification of 'nearshore' and 'offshore' populations that have shown morphological and genetic differences (Hoelzel *et al.* 1998; Hale *et al.* 2000; Wang *et al.* 2000). A new species of inshore bottlenose dolphin was described in 2011 from a very small geographic area of southeastern Australia (Charlton-Robb *et al.* 2011) indicating that the taxonomy of bottlenose dolphin is even more complex. The taxonomy of bottlenose dolphin records in the database is not known and so individual stranding events were classified as *Tursiops* sp.

RESULTS

Species, demographics and event types

A total of 732 cetacean stranding events were recorded along the Western Australian coast between 1981 and 2010, involving 34 species and 1753 individuals (Table 1). For most species, records included stranded individuals from both sexes and from multiple age-classes. Most stranding events involved single animals (n = 681, 93%). Twenty-three events (3%) involved groups of two animals and 32 events (4%) were of three or more (Table 2). Mass strandings (i.e. three or more individuals) were recorded for 11 species. Fifty-nine percent (n = 1034) of the total number of stranded individuals were involved in mass strandings. False killer whales (*Pseudorca crassidens*), long-finned pilot whales (*Globicephala melas*), short-finned pilot whales (*Globicephala macrorhynchus*) and striped dolphins (*Stenella coeruleoalba)* have all mass stranded with more than 20 animals. Only one mixed species mass stranding was recorded during the time

Table 1 Species (grouped by family), sex and age category of individual cetaceans stranded in Western Australia from 1981 to 2010.

Common name	Scientific name	No. of individuals	No. of events	Individuals (sex)			Individuals (age category)			
				M	F	?	A	SA	C	?
Delphinidae										
DOLPHINS										
Indo-Pacific humpback dolphin	*Sousa chinensis*	5	5	4	-	1	1	1	2	1
Bottlenose dolphin	*Tursiops* spp.	371	330	180	103	88	83	98	115	75
Pantropical spotted dolphin	*Stenella attenuata*	7	2	3	4	-	3	4	-	7
Striped dolphin	*Stenella coeruleoalba*	97	27	15	7	75	13	9	3	72
Spinner dolphin	*Stenella longiristris*	6	6	1	3	2	5	-	-	1
Common dolphin	*Delphinus delphis*	30	28	17	5	8	15	3	6	6
Fraser's dolphin	*Lagenodelphis hosei*	1	1	1	-	-	-	1	-	-
Risso's dolphin	*Grampus griseus*	2	2	-	2	-	-	1	1	-
TOOTHED WHALES										
Melon-headed whale	*Peponocephala electra*	1	1	-	-	1	1	-	-	-
Pygmy killer whale	*Feresa attenuata*	1	1	1	-	-	-	1	-	-
False killer whale	*Pseudorca crassidens*	397	18	6	6	385	6	7	-	384
Killer whale	*Orcinus orca*	8	2	1	2	5	1	-	2	5
Short-finned pilot whale	*Globicephala macrorhynchus*	52	7	1	2	48	10	2	1	39
Long-finned pilot whale	*Globicephala melas*	446	22	23	15	408	20		9	417
Physeteridae										
Sperm Whale	*Physeter macrocephalus*	57	36	12	14	31	15	2	6	34
Kogiidae										
Pygmy sperm whale	*Kogia breviceps*	18	18	3	8	7	8	2	8	-
Dwarf sperm whale	*Kogia simus*	5	4	-	4	1	2	3	-	-
BALEEN WHALES										
Balaenidae										
Southern right whale	*Eubalaena australis*	6	6	1	2	3	3		1	2
Neobalaenidae										
Pygmy right whale	*Caperea marginata*	6	6	3	1	2	2	2	1	1
Balaenopteridae										
Minke whale	*Balaenoptera acutorostrata*	22	22	4	7	11	-	3	15	4
Bryde's whale	*Balaenoptera edeni*	1	1	-	-	1	-	1	-	-
Blue whale	*Balaenoptera musculus*	1	1	1	-	-	1	-	-	-
Pygmy blue whale	*Balaenoptera musculus brevicauda*	4	4	1	3	-	4	-	-	-
Fin whale	*Balaenoptera physalus*	2	2	1	1	-	1	1	-	-
Humpback whale	*Megaptera novaeangliae*	139	138	42	27	70	24	22	81	12
BEAKED WHALES										
Ziphiidae										
Cuvier's beaked whale	*Ziphius cavirostris*	4	4	-	2	2	-	3	-	1
Arnoux's beaked whale	*Berardius arnuxii*	1	1	1	-	-	1	-	-	-
Shepherd's beaked whale	*Tasmacetus shepherdi*	4	2	-	1	3	1	-	-	3
Andrew's beaked whale	*Mesoplodon bowdoini*	2	2	2	-	-	-	1	1	-
Blainville's beaked whale	*Mesoplodon densirostris*	1	1	1	-	-	-	1	-	-
Gray's beaked whale	*Mesoplodon grayi*	40	22	11	15	14	7	6	14	13
Hector's beaked whale	*Mesoplodon hectori*	2	2	-	2	-	1	1	-	-
Strap-toothed beaked whale	*Mesoplodon layardii*	8	4	2	-	6	2	-	1	5
True's beaked whale	*Mesoplodon mirus*	6	4	4	2	-	1	-	3	2
	TOTAL:	**1753**	**732**	**342**	**238**	**1172**	**231**	**175**	**270**	**1084**

A, adult; SA, subadult; C, calf; ?, not recorded or could not be determined in the field.

period considered in this study. It occurred at Hamelin Bay in March 2009 and involved 87 long-finned pilot whales and five bottlenose dolphins. There is an unusual record of two humpback whales stranding together at the Abrolhos Islands. These individuals were caught in a lagoon and were both returned to deeper water when the tide changed.

The largest mass stranding involved at least 320 long-finned pilot whales that came into the shallows at Dunsborough. This number was estimated from aerial photographs of the incident when 19 individuals came ashore and died and the rest of the pod were also expected to have stranded without the fast response and persistence of rescuers to herd the pod back to deeper waters.

Species that rarely stranded (less than five records) were Risso's dolphin (*Grampus griseus*), Fraser's dolphin (*Lagenodelphis hosei*), pygmy blue whale (*Balaenoptera*

Table 2 Cetacean stranding events along the Western Australian coast for species that had stranding events involving more than one animal between 1981 and 2010. Events involving three or more individuals are considered mass strandings.

Species	Number of individuals							
	1	2	3–5	6–10	11–20	21–50	51–100	101–320+
Delphinidae								
Bottlenose dolphin	313	11	3	3	-	-	-	-
Pantropical spotted dolphin	1	-	-	1	-	-	-	-
Striped dolphin	22	1	1	1	-	2	-	-
Common dolphin	26	2	-	-	-	-	-	-
False killer whale	12	1	1	-	-	-	2	2
Killer whale	1	-	-	1	-	-	-	-
Short-finned pilot whale	5	-	-	1	-	1	-	-
Long-finned pilot whale	18	1	-	-	1	-	1	1
Physeteridae								
Sperm whale	33	-	1	2	-	-	-	-
Kogiidae								
Dwarf sperm whale	3	1	-	-	-	-	-	-
Balaenopteridae								
Humpback whale	138	1	-	-	-	-	-	-
Ziphiidae								
Shepherd's beaked whale	1	-	1	-	-	-	-	-
Gray's beaked whale	14	3	4	1	-	-	-	-
Strap-toothed beaked whale	3	-	1	-	-	-	-	-
True's beaked whale	2	2	-	-	-	-	-	-

musculus brevicauda), pygmy sperm whale (*Kogia breviceps*), dwarf sperm whale (*Kogia simus*), Arnoux's beaked whale (*Berardius arnuxii*), Blainville's beaked whale (*Mesoplodon densirostris*) and Hector's beaked whale (*Mesolpodon hectori*). Many of these species are considered rare but some simply do not strand often (e.g. pygmy blue whale). Dolphins were involved in the largest number of events (401) whereas beaked whales were involved in the fewest events (42). The species that accounted for the most stranding events was the bottlenose dolphin (330), whilst the long-finned pilot whale accounted for the most individuals (446).

Thirty-four species were recorded as stranded during this study including three species not recorded by Bannister *et al.* (1996) bringing the total number of species recorded for Western Australia to 40. The additional species were Fraser's dolphin, pygmy blue whale and Hector's beaked whale.

The demographics of stranded cetaceans are shown in Table 1. There is a male bias in strandings of dolphins in the Delphinidae group with 64% of those sexed being male (n = 343). Individual species that demonstrated a clear male bias in stranding were humpback whales (61%, n = 69) and bottlenose dolphins (64%, n = 283). There was some evidence that bottlenose dolphins sometimes stranded in all-male groups, with two strandings of all-male groups of four and 10 individuals in the Mandurah Region. Sex and length (and therefore age) were recorded for only a small proportion of stranded toothed whales, 12 and 13%, respectively.

Among baleen whales, calves accounted for 60% of the individuals for whom length was measured or estimated (and therefore age could be estimated). A bias towards more calves stranding was observed for a number of species. Calves accounted for 31% of bottlenose dolphin strandings, 58% of humpback whale (*Megaptera novaeangliae*) strandings, 68% of minke whale (*Balaenoptera acutorostrata*) strandings and 35% of Gray's beaked whale (*Mesoplodon grayi*) strandings. For stranded sperm whales (Physeteridae and Kogiidae), 54% of strandings were considered adults based on length.

Spatial distribution of strandings

Stranding events recorded in the database were not evenly distributed along the Western Australian coastline (Figure 1). The greatest density of strandings were recorded close to areas of high human population density. Very few strandings have been recorded from the Kimberley, Pilbara and Nullabor coasts.

A large number of bottlenose dolphin and humpback whale strandings have been recorded in the database so it was considered useful to investigate any spatial trends observed in these data separately. These two species collectively account for almost two thirds (n = 468 of 732, 63.9%) of stranding events (45.1% and 18.9% for each species, respectively).

The majority of bottlenose dolphin records were from the Swan River, Mandurah Estuary/Peel Inlet and Bunbury harbour areas and the coastline in between (Figure 2). Woodman Point was also a common place for bottlenose dolphin to strand. There were several records from Shark Bay where there has been ongoing research into bottlenose dolphins for many years and a general public interest because of the group of dolphins habituated to being fed at Monkey Mia.

Humpback whales have a geographical spread of records similar to bottlenose dolphins but are less concentrated between Perth and Mandurah (Figure 3). A cluster of 15 humpback whale strandings occurred along the 28km length of coast between Marmion and Alkimos and another cluster of six strandings along a 14km length of coast between Wedge Island and Lancelin. The North

Figure 1. Distribution of cetacean stranding records in Western Australia summarised by Integrated Marine and Coastal Regionalisation of Australia meso-scale bioregions, 1981–2010.

West Cape, particularly the northern third of the peninsula, also accumulated a cluster of strandings with eight records for the area.

Most mass strandings have occurred in the vicinity of Busselton and Augusta in the southwest Capes region (Figure 4). In addition, four mass strandings of bottlenose dolphins have occurred in the Mandurah area together with more than 40 strandings of individuals or mother and calf pairs making it a common area for bottlenose dolphin strandings. These strandings are predominantly associated with spring tides, the dolphins being caught in shallow water or on mudflats of the estuary.

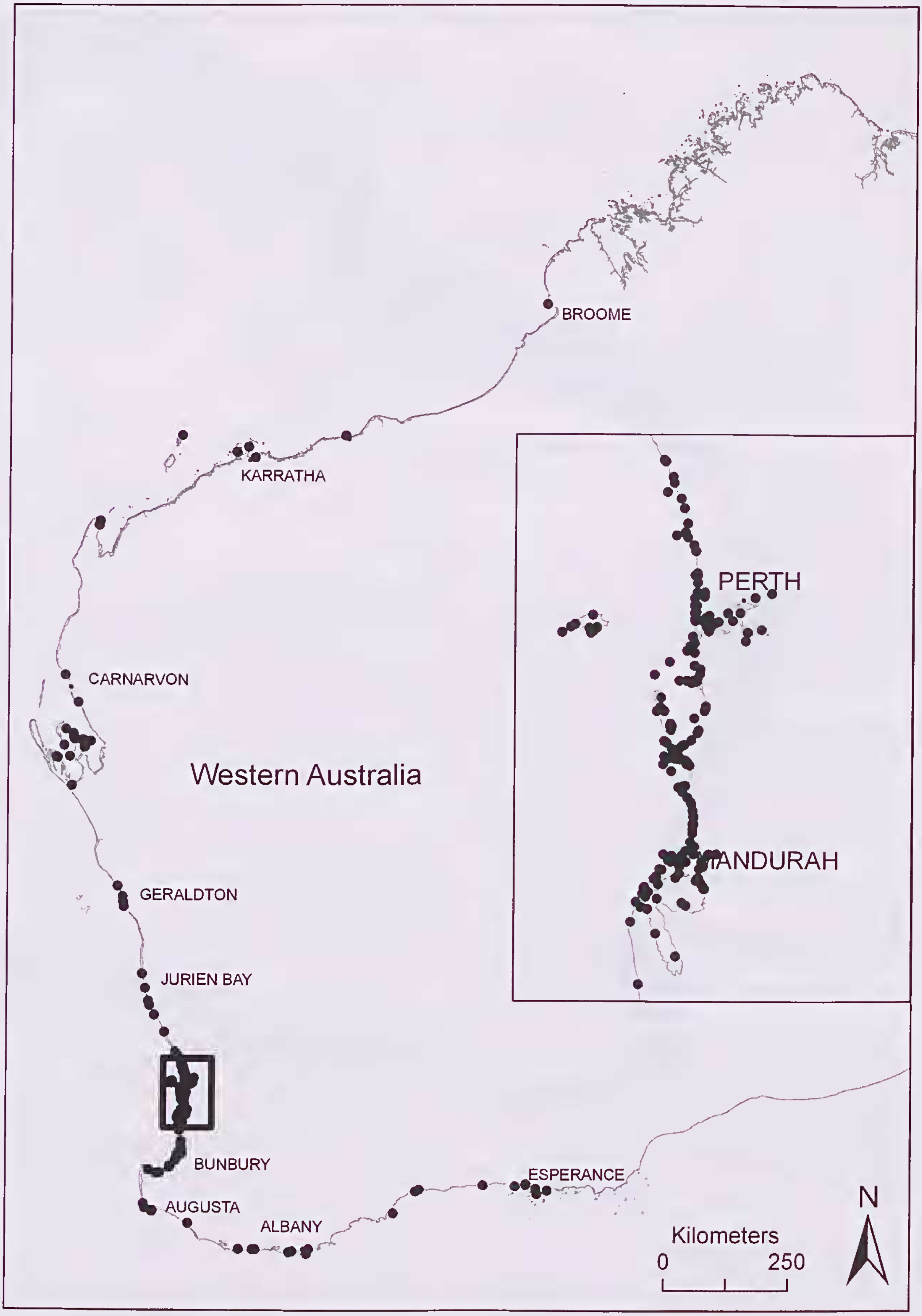

Figure 2. Distribution of bottlenose dolphin strandings from Western Australia 1981–2010.

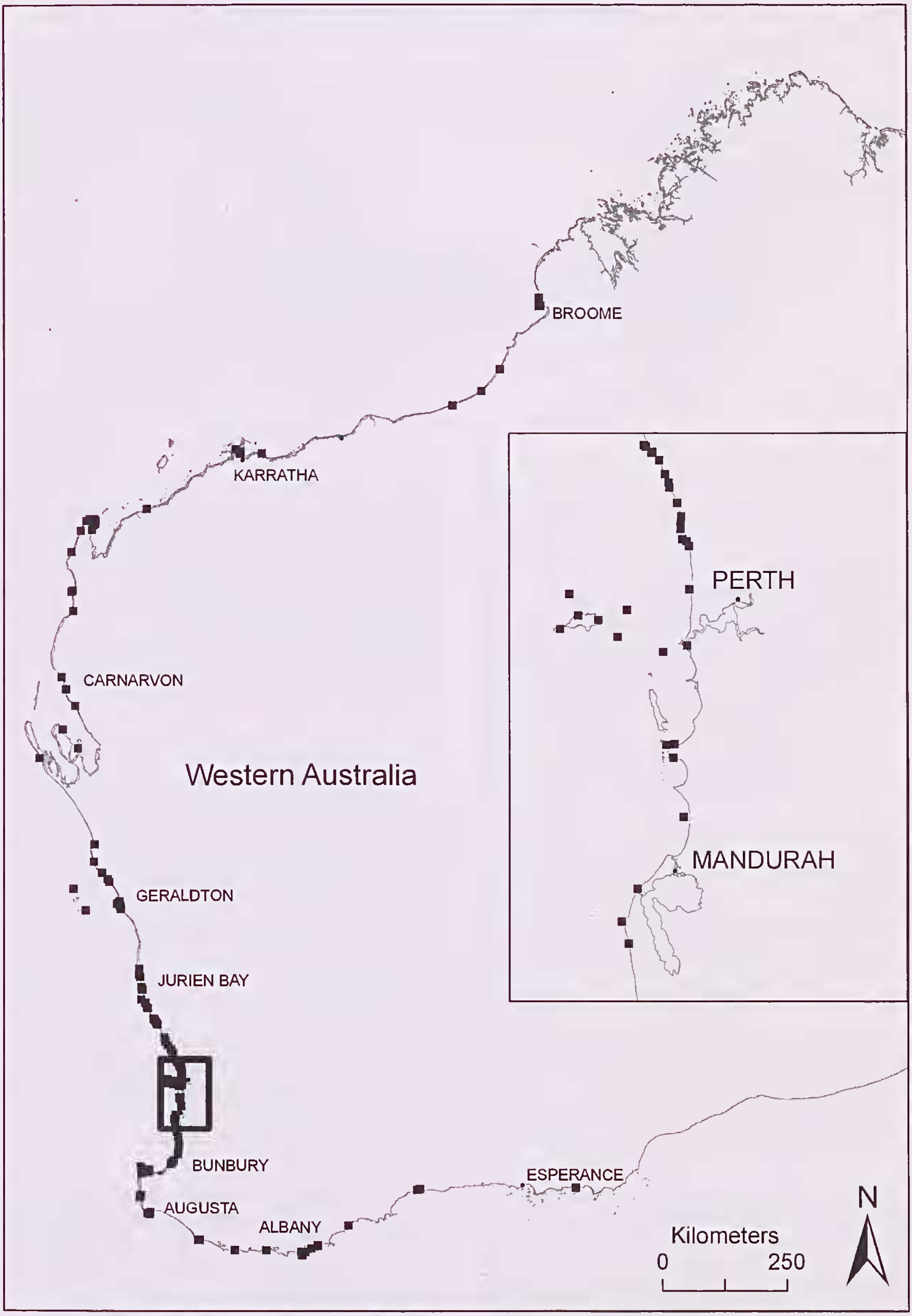

Figure 3. Distribution of humpback whale strandings 1981–2010.

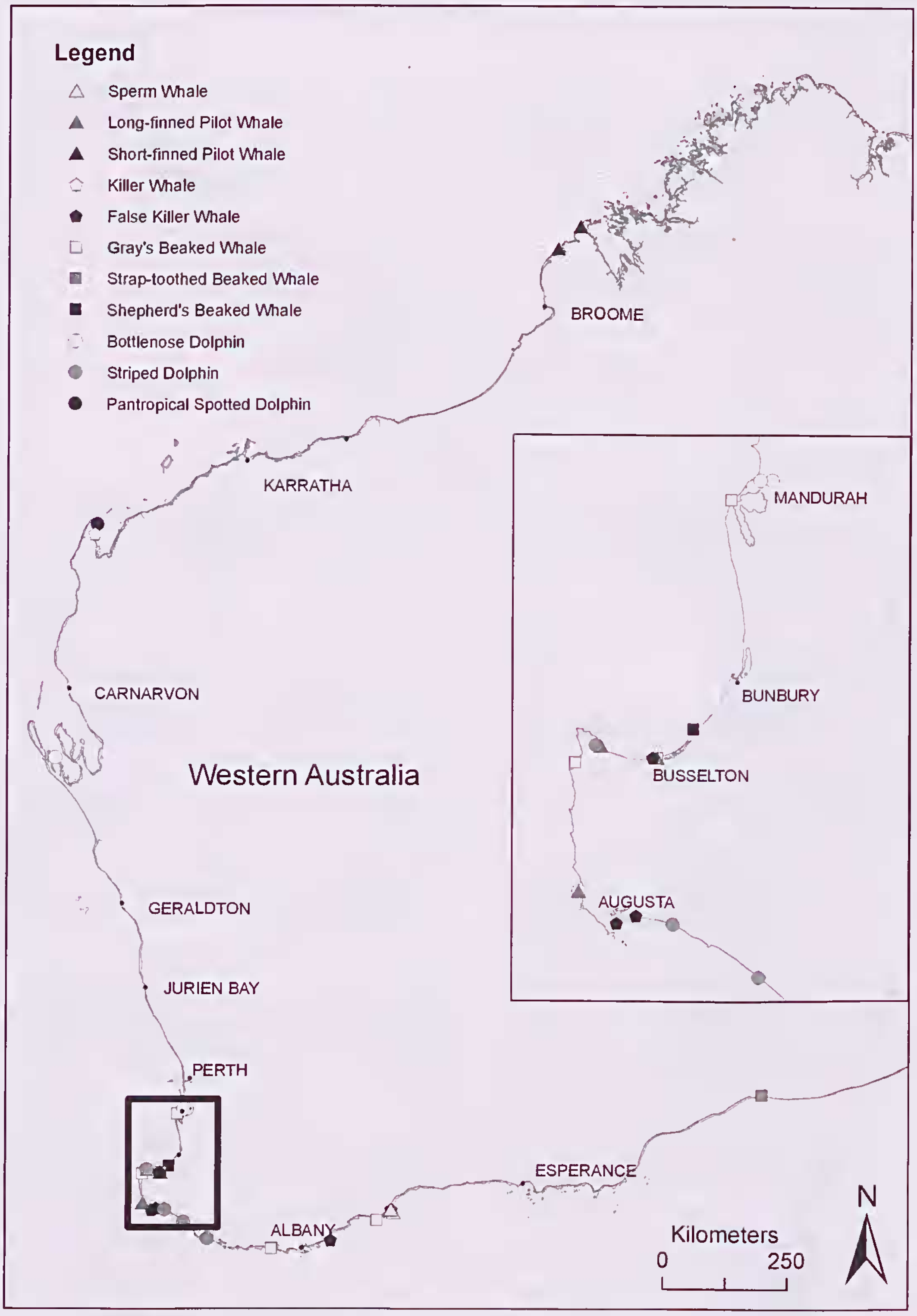

Figure 4. Locations of mass stranding events of cetaceans (3 or more individuals) in Western Australia 1981–2010.

Temporal distribution of strandings

The number of stranding events recorded in the Western Australian Cetacean Stranding Database each year is shown in Figure 5. The frequency of strandings has remained relatively stable over the 29 years with 24 (± 4) events per year. An obvious exception is 2009 when an unusually high number of bottlenose dolphin (n = 36) and humpback whale (n = 46) strandings occurred.

A species with an apparent change in frequency of strandings over time is the common dolphin (*Delphius delphis*) (Figure 6). The majority of stranding events for the species occurred between 1985 and 1997 (26 events) after which only two stranding events have been recorded, both in 2010.

For each species listed in Table 3, the observed seasonal distribution of strandings was compared to an

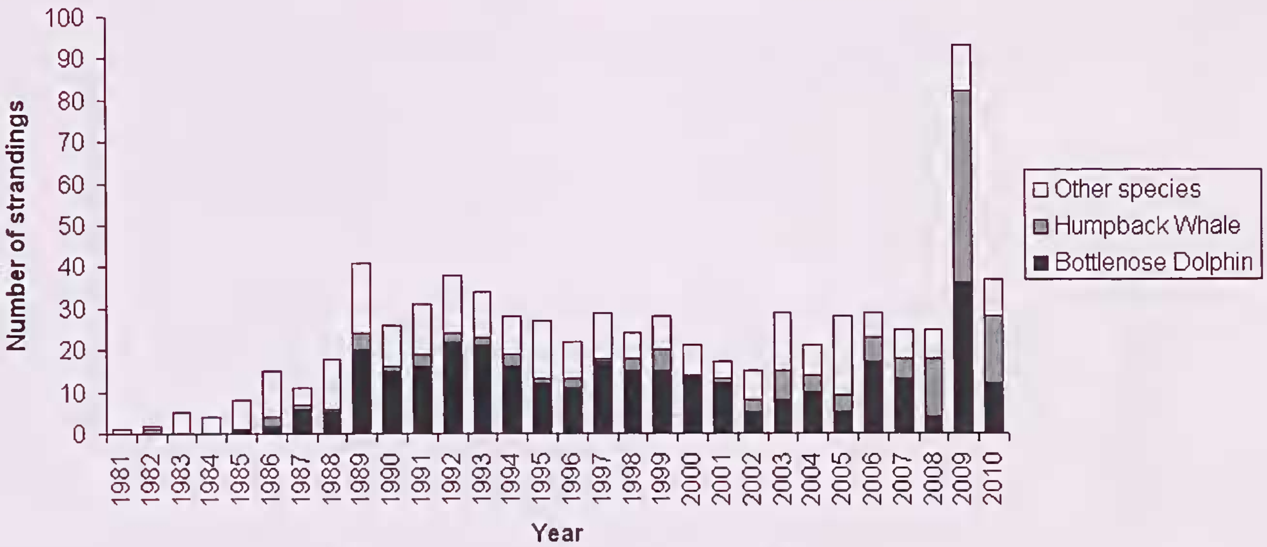

Figure 5. Number of cetacean stranding records for Western Australia over time 1981–2010.

expected even distribution of strandings across all seasons using a Pearson's chi-squared test. Seasonal stranding patterns differed significantly from expected even-seasonal distribution for bottlenose and common dolphins, minke, humpback and Gray's beaked whales. All other species showed no significant differences. Strandings peaked in spring for minke, humpback and sperm whales, whereas autumn was the peak for bottlenose, striped and common dolphins. Gray's beaked whale strandings peaked in summer. There were fewer strandings of dolphins in winter months than any other season.

Outcomes and fate

Of the 1753 cetaceans stranded along the Western Australian coast between 1981 and 2010, 695 were found dead and 1047 were found alive (Table 4). Of those found alive, 70% were returned to deeper water and although the ultimate fate of those individuals is largely unknown, 6% of those returned to deeper water are known to have restranded. In an attempt to determine the fate of cetaceans returned to deeper water, individual identification numbers were freeze branded onto 65 individuals (from seven species) that were returned to deeper water. Of the animals which were freeze branded, the only individuals that were resighted were bottlenose dolphins. A few freeze branded bottlenose dolphins that inhabit the Mandurah area have stranded multiple times.

Toothed whales were much more likely to be returned to deeper water (62%) (irrespective of ultimate fate/ outcome of the individuals) than baleen whales (only 8% returned to deeper water). Most stranding records of dolphins and baleen whales were carcasses (69% of each group). A higher proportion of beaked whales were observed to strand whilst alive and subsequently die (34%) than any other group. Many of these individuals were noted in the database to have died shortly after stranding. Beaked whales were sometimes seen milling around close to shore in the days or weeks leading up to a stranding event that drew public attention and meant they were more likely to be observed soon after they stranded.

A total of 58 individuals representing 12 species were euthanased by DEC staff or veterinarians. Euthanasia was performed primarily on individuals from mass-stranding events or on baleen whales. A total of 13 individuals out of 139 strandings of humpback whales were euthanased. The technique developed for euthanasia of humpback whales through the experience of these strandings is described in Coughran *et al.*[2012 (in press)].

Table 3 Seasonal distribution of stranding events and chi-squared values for species where the sample size of stranding events was < 20 between 1981 and 2010.

Species	Summer Dec-Feb	Autumn Mar-May	Winter Jun-Aug	Spring Sep-Nov	χ^2	df	P
Bottlenose dolphin	82	97	57	94	12.036	3	0.007
Striped dolphin	6	9	4	8	2.185	3	0.534
Common dolphin	8	14	3	7	11.714	3	0.008
Long-finned pilot whale	7	3	6	6	1.64	3	0.650
Minke whale	1	1	7	12	16.143	3	0.001
Humpback whale	8	4	51	75	102.754	3	<0.0001
Sperm whale	9	5	8	12	2.941	3	0.401
Gray's beaked whale	17	4	1	0	33.640	3	<0.0001

Table 4 Outcomes and fate of individual cetaceans stranded along the Western Australian coast between 1981 and 2010.

Species	Found dead	Died	Euthanased	Returned deeper water	Restranded and died	Restranded and euthanased	Restranded and returned to deeper water	Taken into care and died	Taken into care and returned to deeper water	Unknown	TOTAL
Delphinidae											
Indo-Pacific humpback dolphin	4	-	-	1	-	-	-	-	-	-	5
Bottlenose dolphin	267	22	2	71	2	-	1	-	-	6	371
Pantropical spotted dolphin	1	6	-	-	-	-	-	-	-	-	7
Striped dolphin	54	20	2	12	1	1	5	1	1	-	97
Spinner dolphin	6	-	-	-	-	-	-	-	-	-	6
Common dolphin	27	1	-	2	-	-	-	-	-	-	30
Fraser's dolphin	-	1	-	-	-	-	-	-	-	-	1
Risso's dolphin	-	1	1	-	-	-	-	-	-	-	2
Melon-headed whale	-	1	-	-	-	-	-	-	-	-	1
Pygmy killer whale	1	-	-	-	-	-	-	-	-	-	1
False killer whale	28	70	22	261	15	1	-	-	-	-	397
Killer whale	3	-	-	3	1	-	1	-	-	-	8
Short-finned pilot whale	5	47	-	-	-	-	-	-	-	-	52
Long-finned pilot whale	92	24	3	319	4	3	-	1	-	-	446
Physeteridae											
Sperm whale	38	18	1	-	-	-	-	-	-	-	57
Kogiidae											
Pygmy sperm whale	13	1	1	-	1	2	-	-	-	-	18
Dwarf sperm whale	4	-	1	-	-	-	-	-	-	-	5
Balaenidae											
Southern right whale	6	-	-	-	-	-	-	-	-	-	6
Neobalaenidae											
Pygmy right whale	5	-	-	-	-	1	-	-	-	-	6
Balaenopteridae											
Minke whale	11	2	3	5	-	-	-	-	-	1	22
Bryde's whale	1	-	-	-	-	-	-	-	-	-	1
Blue whale	1	-	-	-	-	-	-	-	-	-	1
Pygmy blue whale	4	-	-	-	-	-	-	-	-	-	4
Fin whale	1	1	-	-	-	-	-	-	-	-	2
Humpback whale	95	19	13	7	1	-	-	-	-	4	139
Ziphiidae											
Cuvier's beaked whale	1	2	-	1	-	-	-	-	-	-	4
Arnoux's beaked whale	1	-	-	-	-	-	-	-	-	-	1
Shepherd's beaked whale	1	-	-	3	-	-	-	-	-	-	4
Andrew's beaked whale	1	1	-	-	-	-	-	-	-	-	2
Blainville's beaked whale	-	1	-	-	-	-	-	-	-	-	1
Gray's beaked whale	14	11	1	10	3	-	1	-	-	-	40
Hector's beaked whale	1	1	-	-	-	-	-	-	-	-	2
Strap-toothed beaked whale	5	2	-	-	-	-	1	-	-	-	8
True's beaked whale	4	2	-	-	-	-	-	-	-	-	6
TOTAL	695	254	51	695	28	7	9	2	1	11	1753

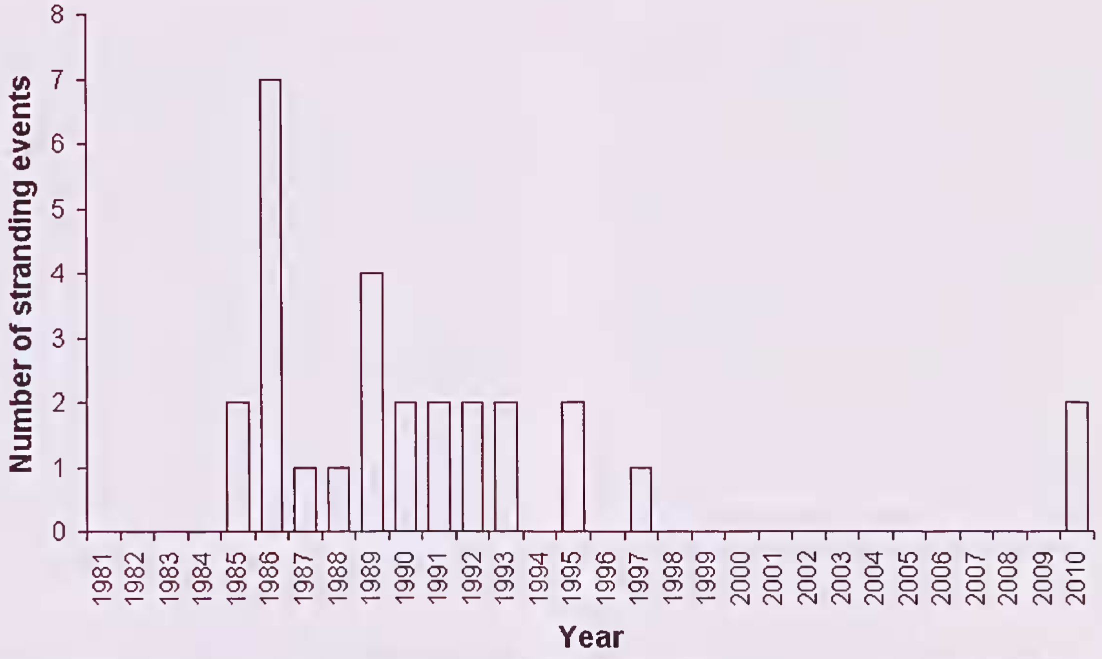

Figure 6. Strandings of common dolphins (*Delphinus delphis*) along the Western Australian coast between 1981 and 2010.

DISCUSSION

The stranding data in the Western Australian Cetacean Stranding Database closely reflected the known cetacean fauna composition of the region according to Bannister *et al.* (1996) but has contributed an additional three species not previously recorded for the region. Stranding databases are known to be useful for recording rare species and have provided comparable cetacean fauna lists to at-sea sightings or boat surveys (Maldini *et al.* 2005; Pikesley *et al.* 2011). Stranding data are better at representing species not easily detected in systematic sighting surveys because of factors such as body size, surfacing behaviour or pelagic life histories (Maldini *et al.* 2005; Danil *et al.* 2010).

Stranding data can provide information on age structure (Evans *et al.* 2002; Evans & Hindell 2004). Mass strandings, where individuals are likely to be from the same social group, are particularly useful for determining age structure. However, in Western Australia, detailed or comprehensive demographic information has not been collected for mass strandings of large numbers of individuals. False killer whales and long-finned pilot whales are well-known for mass stranding and accounted for a large number of the stranded animals recorded in Western Australia in single events but only a small percentage had sex, length and other biological information recorded. This probaby reflects the logistical difficulty in taking observations and measurements from a large number of animals when the management of crowds, human safety and successful return to sea of the animals takes priority. Determination of sex may not be possible if the ventral surface and genital area is not visible and the animal cannot physically be moved.

Recording an estimate of age of stranded cetacean can provide information on age groups within species that are at higher risk of stranding. This has the potential to lead to conservation action if the cause for a particular age group being susceptible is preventable. However, it may also simply provide information on the natural mortality rates of a species. A large proportion (31%) of bottlenose dolphin strandings in Western Australia were calves. This is consistent with findings from Shark Bay that show natural calf mortality to be 44% of calves before age three (Mann *et al.* 2000). In contrast, Kemper & Ling (1991) reported that calves only accounted for 9% of bottlenose dolphin strandings in South Australia.

Stranding data can also show seasonal trends which provide information about migration or movements patterns of cetacean species (Danil *et al.* 2010). For humpback whales and minke whales in Western Australia the peak in strandings (predominantly calves) between July and November coincides with their known migratory patterns and breeding season for the region (Kasamatsu *et al.* 1995; Jenner *et al.* 2001). For Gray's beaked whale the reason for the seasonality of strandings is unknown but it may be related to ocean temperatures with the waters off the south coast and southwest corner of the State being cooler in the summer months due to ocean currents. In summer, the Leeuwin Current that brings warm water southwards is weakest and the Cape Current which brings cool water northwards around the southwest corner of Western Australia is strongest (Pearce & Pattiaratchi 1999). This means that the coastal water temperature is more comparable to the subantarctic and temperate waters that Gray's beaked whale is known to inhabit (Bannister *et al.* 1996).

The majority of common dolphin strandings occurred along the south coast between 1985 and 1995 which is a period when the seasonal catch of the west coast purse-seine fishery was high (Molony & Lai 2010). Common dolphins are known to have been taken by this fishery with 33 entanglement deaths reported between 1989 and 1994 (Gales *et al.* 2003). It is likely that some of the strandings recorded during the period were associated with the fishery (e.g. bycatch) or were attracted to the area by the same fish stocks that were being targeted by the fishery. The fishery collapsed when mass mortalities of Australian pilchards occurred in 1995 and 1998/99 (Gaughan *et al.* 2000), after which very few common dolphin strandings have been recorded.

Other studies have reported an increase in the number of strandings reported each year over time (Norman *et al.* 2004; Maldini *et al.* 2005; Leeney *et al.* 2008; Aragones *et al.* 2010; Danil *et al.* 2010). This has been attributed to an increase in the number of observers and observer effort. For Western Australia, except for 2009, the number of strandings reported each year is relatively consistent.

An unusually high number of bottlenose dolphin and humpback whale strandings occurred in 2009. The dolphin strandings included the recovery of six bottlenose dolphin carcasses within the Swan–Canning Estuary over a five-month period (Beazley 2010; Holyoake *et al.* 2010). Post-mortem examination of four dolphins found that the mortalities were associated with viral, bacterial, and/or fungal infection and identified entanglement injuries, contaminant burdens, and stress from human activities as potential contributing factors. The increase in humpback whale strandings is being investigated and will be reported elsewhere. Investigations are focusing on evidence for the population reaching carrying capacity. A large proportion (61%) of the 2009 strandings of humpback whales were calves and this bias towards very young animals stranding was also evident in 2008 and 2010.

As discussed by Norman *et al.* (2004) many factors can potentially affect the observed distribution and frequency of strandings. The most obvious factors relate to the underlying abundance of species and the probability of detection given human population density. Other factors relate to our ability to find the carcass or for it to reach the shore before it sinks, decomposes, becomes scavenged or is taken back out to sea by tides. Factors such as ocean currents, weather patterns, coastline geography and undersea topography also affect where and when a cetacean may reach the shore. All these factors make it difficult to draw conclusions about the distribution and abundance of species based on stranding data.

It is common for a greater number of strandings to be reported from areas with high human population density (Kemper & Ling 1991; Maldini *et al.* 2005). The Western Australian coastline is extensive and many areas, particularly in the north of the State, are sparsely populated. Very few strandings have been recorded from the sparsely populated Kimberley, Pilbara and Nullarbor coasts. These regions are remote and often have poor access to the coast both from the land (e.g. few roads) and from the sea (e.g. rocky shores or cliffs). It is difficult to maintain an active stranding network in sparsely populated areas and a large amount of effort would be required to extend reporting networks to be consistent along the entire coastline (Maldini *et al.* 2005). The logistics and cost of responding to strandings in remote stretches of coastline mean that many cetaceans will be found long after the initial stranding, if at all. This must be acknowledged as a limitation of the data, and must be considered in any spatial analysis of the fate of stranded animals.

Spatial and temporal patterns in observation effort may also result in a bias in the species reported or season in which most strandings are reported. The trend for a large portion of dolphin and Gray's beaked whale records to be observed in warmer months could be an artefact of a greater number of potential observers visiting and spending time on beaches during summer for recreation (Kemper & Ling 1991; Norman *et al.* 2004). The high number of reported bottlenose dolphin strandings is likely a result of the significant overlap in their preferred habitat and the coastal and estuarine areas frequented by people, but it may also be attributed to a particular interest in the community for that species. Bottlenose dolphins inhabit areas popular for water-based recreation and sometimes actively interact with fishing boats (Finn *et al.* 2008; Donaldson *et al.* 2010) and swimmers making them highly visible to people. Bottlenose dolphins are a well-studied cetacean species in Western Australia and so the high number of reported strandings may be partly a result of this concerted scientific effort and scientific interest.

The concentration of stranding records that occurred in the southwest of the State may not simply be related to observer effort and population density. The southwest corner of Western Australia has tidal and geographical features that mean there is a greater potential for strandings to occur and for them to then be observed than in the north of the State. The difference between high tide and low tide is far greater in the north of Australia, especially the Canning IMCRA bioregion (Interim Marine and Coastal Regionalisation for Australia Technical Group 1998), meaning any carcass washed ashore is likely to be washed back out to sea with the next high tide which reduces the time available to observe and report the carcass. The south coast is a complicated coastline consisting of a series of sandy lunate bays with rocky headlands that can potentially snag dead or moribund cetaceans. The continental shelf is also closer to shore in the south compared to the north of the State which increases the chance of pelagic species coming close to the coast and stranding or being washed ashore in an intact state. Kemper & Ling (1991) discuss the complexity of coastlines and shallowness of waters offshore between States in Australia in relation to the number of mass-stranding events and conclude States with shallow waters and/or an uncomplicated coastline have fewer mass strandings (i.e. South Australia, Victoria, Queensland, New South Wales).

Strandings may also be more abundant in some areas because the productivity of the marine environment is high due to certain oceanographic features such as where upwellings occur or where deep sea canyons are present (Kemper & Ling 1991). An extremely large deep sea canyon is present off Perth and there are numerous smaller canyons along the south coast (Harris *et al.* 2003). The Perth Canyon is known to promote localised upwelling and enhances both the production and physical aggregation of plankton that attracts feeding pygmy sperm whales (Rennie *et al.* 2009).

Management implications

This study has aimed to describe the cetacean fauna of Western Australia, identify any spatial and temporal patterns of strandings and assess the outcomes of stranding events. The efficiency of the stranding reporting and response network has not been the focus of this study but it may be worthy of further investigation and review. The Western Australian Cetacean Stranding Database contains a high proportion of events where the animals were reported as stranding live (60%) and therefore required some form of assistance. In comparison, in South Australia only 15% of stranding records involved animals which were reported as stranding alive (Kemper & Ling 1991). The high proportion of live strandings reported in Western Australia is likely to be attributable to the nature of the datasets. The dataset used by Kemper & Ling (1991) utilised museum specimens whereas the dataset used for this study records incidents where a management response was required and is therefore more likely to contain live strandings where rescue was attempted. Of those found stranded alive in Western Australia, over 70% were rescued (i.e. returned to deeper water). A review of the stranding reporting and response network would be beneficial to identify aspects that work well and those that require improvement.

Each record of a stranded cetacean in the Western Australian Cetacean Stranding Database required some kind of management action by DEC. At the most basic level, the reporting of a cetacean carcass may have required an investment of time to acquire relevant information and to enter the relevant details into the database. Reports of live strandings usually required a much more elaborate management response. Based purely on the number of recorded stranding events, bottlenose dolphins and humpback whales required the largest commitment of resources in Western Australia. These two species also accounted for a large number of individuals reported stranding alive, and of the individuals requiring some form of management response such as an effort to return the animals to deeper water or to undertake euthanasia. Other notable species requiring investments of resources to support management responses were those species that mass strand, particularly long-finned pilot whales and false killer whales. Mass-stranding events require a disproportionate amount of time and resources to manage than events involving single individuals. Mass strandings involve a large number of volunteers to coordinate, significant public attention and difficult logistics to undertake the rescue operations (Edwards 1987; McNamara 1987; Mell 1988).

Management of strandings is different for each group. Dolphins and beaked whales generally strand individually or in small groups, and their physical size enables them to be handled by fewer people with less mechanical assistance. Baleen whales almost exclusively strand individually and do not lend themselves to rescue because stranded individuals are often in very poor condition and their weight and size makes moving them without injury extremely difficult. Management of baleen whale strandings primarily involves crowd management, euthanasia, appropriate carcass disposal and hygiene protocols. Toothed whales that mass strand require large logistical support to manage volunteers and coordinate rescue attempts. Having a pre-prepared general response plan for groups of cetacean species and incident types assists in providing an efficient and appropriate response.

The DEC has adopted the Australian Inter-Service Incident Management System (AIIMS) (http://knowledgeweb.afac.com.au/training/aiims accessed 2 March 2012), which provides a total systems approach to all incident management involving risk. The management system is a structure that ensures all vital management actions and procedures are undertaken properly. It is a modular structure that expands or contracts depending on the size or stage of the incident (i.e. one animal involving one person undertaking multiple tasks to multiple animals involving many people with specific tasks).

In conclusion, the study of strandings in the Western Australian Cetacean Stranding Database has provided a comprehensive list of cetacean fauna recorded in Western Australia. The dominance of bottlenose dolphins and humpback whales in the stranding record indicate that these species require particular attention to ensure management resources are allocated most effectively in the future. The spatial pattern of strandings and mass strandings confirms that the southwest of the State is currently, and will likely remain, the region of the greatest number of reported stranding events.

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